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A QUALITATIVE ASSESSMENT OF THE RISK OF FOOT AND MOUTH DISEASE OUTBREAKS OUTSIDE THE WESTERN BOUNDARY OF KRUGER NATIONAL PARK

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SUMMARY

Since the year 2000 at least five declared outbreaks of foot and mouth disease (FMD) have occurred in the area adjacent to the Kruger National Park (KNP) despite the implementation of control measures. Although only one of these outbreaks threatened the free zone, it is necessary to develop decision tools in order to help in the implementation of efficient disease control strategies. To address this issue, a qualitative risk assessment was performed to evaluate the risk of FMD outbreaks of KNP origin occurring across the park's Western Boundary. The OIE assessment method was used based on data collected during a three month period between February and May 2007 and expert opinion. Although the data were not sufficient to allow a quantitative risk assessment to be performed, the investigation served as a useful initial approach prior to undertaking a quantitative risk assessment. Risk was assessed using the following parameters: prevalence of infection in buffalo in the KNP, permeability of the fence along its Western Boundary, the potential for contacts between livestock and buffalo, the level of immunity in cattle herds and the efficiency of surveillance measures. The magnitude of the consequences is derived from the probability of transmission and spread. The method and results are presented to serve as a basis for further discussion and for the development of a quantitative risk assessment model.

INTRODUCTION

The development of transfrontier conservation areas (TFCAs) represents substantial challenges for animal disease control. The increase of habitats for wildlife provides larger geographic areas for the reproduction and dispersal of wild species and their pathogens, therefore multiplying the chances of animal health interactions at the wildlife/livestock interface (Bengis 2005). South Africa is unique regarding the management of control of foot and mouth disease virus (FMDV) where the disease is endemic only in the Kruger National Park (KNP), with all three SAT viruses (SAT 1, 2 & 3) efficiently

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maintained in the resident African buffalo (*Syncerus caffer*) populations. Animal health authorities of South Africa have been efficient in containing the disease within the borders of the KNP by the application of different control and preventive measures. These measures consisted of the erection of a 400km perimeter fence along the Western Boundary of KNP, adjacent area zonation with the application of serial vaccination programmes around the KNP in the immediate buffer zone, intensive surveillance measures by means of regular inspections in the buffer and surveillance zones, and movement control of cloven hoofed animals and their products between zones. Due to the success in containing the disease, the country was granted zoned FMD-free status without vaccination by the *Office International des Epizooties* (OIE) in 1996. Indeed, prior to 2000, the last outbreak of the disease in domestic stock in the FMD free zone had occurred in 1957 and the last outbreak in the buffer zone occurred in 1983. However, between 2000 and 2007, at least 5 outbreaks with confirmed origins from KNP wildlife have occurred along the Western Boundaries of the KNP, some reaching the outskirts of the free zone and threatening agricultural exports on one occasion. Despite having had one outbreak beyond the buffer zone in 2000, South Africa has managed to regain its FMD free zoned status. All these outbreaks were successfully contained after varying periods of time. However, the reasons for the increased incidence of FMD outbreaks need to be analysed. To improve our understanding of the dynamics of the disease and its control systems, a comprehensive qualitative risk assessment of the occurrence of FMD outbreaks outside the KNP was performed.

MATERIALS & METHODS

The method used to conduct this qualitative risk assessment is based on the OIE *Terrestrial Animal Health Code* normally applied to manage the risks associated with imports of live animals and animal products (Murray 2004). The theoretical bases for any risk assessment, whether qualitative or quantitative, are the same. Once the hazard has been identified, in this case, an FMD outbreak, the risk to be assessed is a function a) of the probability that infection will occur and b) of the magnitude of the consequences of such an occurrence. The probability of occurrence of the outbreak is in turn the product of the release assessment of FMDV from the KNP to adjacent provinces and the probability of exposure of cattle herds to the virus. The appraisal of the magnitude of the consequences must take into account both the probability of dissemination of the pathogen (transmission plus spread) and the economic impact of the disease. For a qualitative assessment different authors propose each of these events to be characterised by a number of parameters and each parameter to be analysed on the basis of all available information (Murray 2004, Zepeda 1998). In addition, the probability of occurrence of each event is assessed for classification by means of the following descriptive scale:

- Negligible, when the probability of occurrence of the event is sufficiently low to be ignored, or if the event is possible only in exceptional circumstances
- Low, when the occurrence of an event is a possibility in some cases

– Moderate, when the occurrence of the event is a possibility

– High, when the occurrence of the event is clearly a possibility.

These parameters are subsequently combined with each other according to a matrix (Murray 2004, Zepeda 1998) to give an overall idea of risk.

In this study, the probability of occurrence of a hazard (FMDV infection and the consequences of an epizootic) is equal to the probability of escape of the virus (from the KNP to adjacent areas in South Africa) combined with the probability of the exposure of domestic animals susceptible to the pathogen. As FMDV cannot be transmitted to humans, the consequences of an epizootic are solely socio-economic.

RESULTS

1. Hazard identification

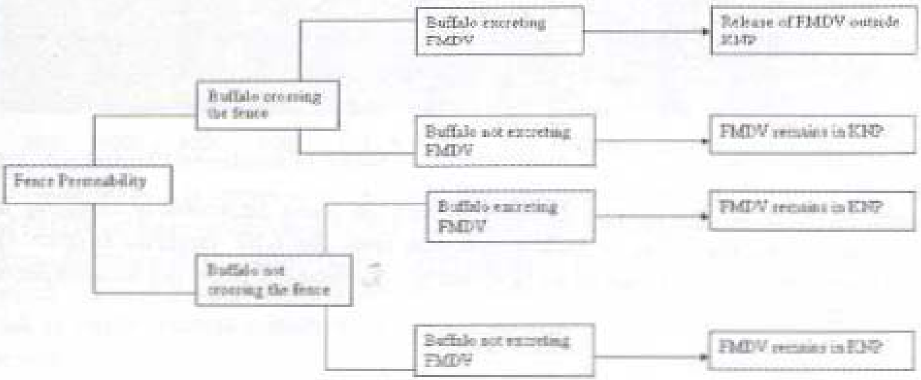
In the present analysis we focused on outbreaks of FMDV occurring along the borders of the KNP produced by buffalo strains (SAT 1, SAT 2 and SAT 3). Although other species of wildlife such as impala and kudu, may be involved in the epidemiology of FMDV in the KNP, we have considered the African buffalo as being the ultimate long-term source of the virus for cattle and the main potential role player in the transmission of FMDV to cattle in South Africa (Vosloo, Bastos, Sahle, Sangaré & Dwarka 2005).

2. Release assessment

The three parameters were examined in order to determine the probability of exit of the virus beyond the Western Boundary of the KNP:

- permeability of the fence
- the prevalence of infection in the buffalo population
- the population density and distribution of buffalo in the KNP

Figure 1: Possible pathway of release of the FMD virus outside the boundaries of the KNP

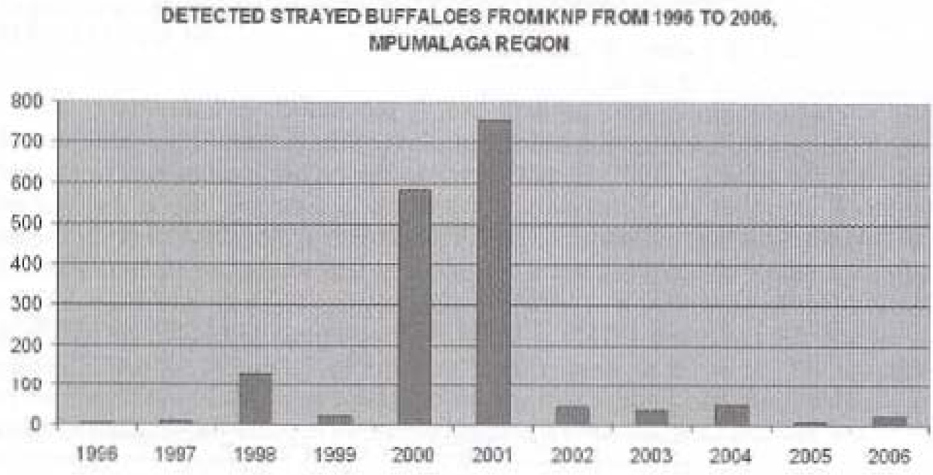


2.1. Fence permeability

The initial KNP disease control fence, erected between 1958 and 1961 to prevent outbreaks of FMD, has been largely successful in limiting wildlife movements for almost a half a century. This fence was upgraded and electrified between 1997 and 1999. Nevertheless, during the last years, its efficiency in deterring large mammals from escaping the KNP has substantially decreased due to a combination of different multiple factors such as:

- A dramatic increase in the elephant population in the KNP resulting in subsequent elephant related fence breaks (up to 45 fence breaks in one year only in Mpumalaga province).
- Increased human/fence line activity: Illegal immigrants from Mozambique (estimated at least 3000/year) are believed to damage the fence at different points and fence components such as batteries and solar panels are regularly stolen. These activities negatively affect the structural integrity of the fence and reduce the deterrent effect of the fence against large mammals.
- Climatic factors: Climatic extremes with major floods have substantially damaged the fence from time to time with the last event in 2000 / 2001. In addition, sections of the fence may also be seasonally damaged at major drainage crossing points and river flows after heavy rains.

Figure 2: Histogram showing detected strayed buffalos from KNP in Mpumalanga region.



All of these factors have a different impact on fence permeability resulting in a substantial number of stray buffalo escaping from the KNP premises (Figure 1). Therefore, the overall probability of KNP buffalo crossing the fence can be considered moderate.

2.2. Prevalence of infection in the buffalo population

Most young buffalo become infected between 3 and 8 months of age, when maternal antibodies wane. In the acute stages of infection, young buffalo excrete FMDV in roughly the same quantities and by the same routes as cattle and are potentially highly infectious (Gainaru, Thomson, Bengis, Esterhuysen, Bruce & Pini 1986). Between May and November, large quantities of virus circulate among buffalo herds and this is the "childhood" epidemic period when they are most likely to be a source of infection for other species (Bastos, Boshoff, Keet, Bengis & Thomson 2000, Thomson 2002). Fourteen days after initial infection, the viruses can no longer be recovered from the tissues, secretions or excretions, with the exception of pharyngeal cells, in about 60% of cases in the so-called "carrier animals" (Anderson, Foggin, Atkinson, Sorensen, Madekurozva & Nqindi 1993). Condy, Hedger, Hamblin & Barnett (1985) demonstrated that FMDV can be maintained in buffalo populations for at least 24 years or longer as long as susceptible cohorts of animals become available on a regular basis. Carriers transmit the infection poorly to cohorts and to other susceptible species (Thomson, Vosloo & Bastos 2003). Nevertheless, although not proven, there is the hypothesis that in certain cases, stress could act as a cause for carrier animals (cattle) to start excreting virus and cause outbreaks (Kitching 2002). This aspect hasn't been sufficiently studied and therefore with the current knowledge available, we can only consider that the probability of finding a potential FMD shedder buffalo in the KNP (a young animal actively infected) as low.

2.3. Population density and distribution of buffalo population in the KNP

The population of buffalo in the KNP has been growing since the last population crash in the early 90's. The current population of buffalo (between 33,000 and 35,000 head) is the highest figure in the last 14 years (R. Bengis, personal communication). Buffalo congregate around sites of available surface water during the dry season between May and November when water is scarce (Keet, Hunter, Bengis, Bastos & Thomson 1996). These high densities of animals, linked with an important circulation of virus between August and November, constitute a high risk virus source around water points and in river beds. These are hot spots for transmission between wildlife species and may compound risk if nearby fences are permeable. Therefore in the dry season, the risk of a susceptible buffalo being a source of infection might increase from low to moderate.

2.4. Assessment of release of FMD

Using the matrix proposed by Zepeda (1998), the authors conclude that the probability of FMDV release outside the KNP is a function of the combination of risks related to the fence permeability (moderate) and the probability of young buffalo excreting the virus which is low in the rainy season and low to moderate in the dry season. Therefore, the risk of FMDV release outside the KNP is rated as low to moderate depending on the season.

3. Probability of exposure

The parameters considered in determining the probability of exposure were as follows:

- o Probability of air-borne virus transmission
- o The potential for transmission from buffalo to susceptible cattle in the buffer zone with vaccination
- o The probability of virus spread within the buffer zone with vaccination
- o The probability of virus transmission among cattle within the buffer zone without vaccination
- o The probability of virus spread outside the buffer zone without vaccination
- o The probability of transmission into the free zone

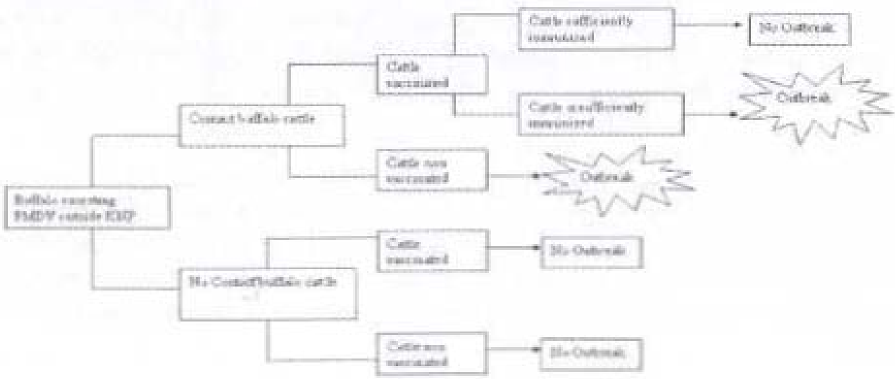
3.1. Probability of air-borne virus transmission

Circumstantial evidence accumulated over many years has indicated that long distance air-borne transmission is highly unlikely in southern Africa. In a quantitative risk assessment in Zimbabwe, the likelihood of this event was considered remote (Sutmoller, Thomson, Hargreaves, Foggin & Anderson 2000). This suggests that potential transmission of FMDV from buffalo to cattle occurs basically by direct contact.

3.2. Probability of contact between buffalo and cattle

Considering the high number of cattle around the KNP, and the gregarious instinct of buffalo, the probability of contact if a small group of buffalo escape from KNP is at least moderate. In fact, a buffalo escaping the KNP will naturally join a cattle herd if it becomes available, searching for the protection of con-specifics particularly in a foreign environment and even more if the buffalo group is small (one or few individuals – especially heifers and young bulls). Older bulls are less likely to socialise with cattle. This risk is higher in areas of communal farming, where densities of cattle are higher and there are fewer fences and will also depend on the amount of time that buffalo

Figure 3: Possible pathway of transmission of FMDV from buffalo to cattle and subsequent spread



remain outside the KNP premises, which on some occasions can remain undetected for several weeks.

3.3. Probability of transmission between cattle and buffalo

Bastos, Bertschinger, Cordel, van Vuuren, Keet, Bengis, Grobler, & Thomson (1999) suggested that sexual transmission of FMDV between male buffalo and cattle can occur. According to different authors, there is evidence that transmission from infected buffalo to cattle occurs fundamentally during acute stages of the disease (Thomson, Vosloo & Bastos 2003, Vosloo, Bastos, Sangare, Hargreaves & Thomson 2002). The occurrence of carriers in transmitting virus has only rarely been found (Dawe, Flanaghan, Madekurozwa, Sorensen, Anderson, Foggin, Ferris & Knowles 1994, Dawe, Sorensen, Ferris, Barnett, Armstrong & Knowles 1994, Kitching 2002, Vosloo, Bastos, Kirkbride, Esterhuysen, Janse van Rensburg, Bengis, Keet & Thomson, 1996).

Therefore, the probability of transmission of FMDV when an escaped buffalo comes into contact with cattle outside the KNP in the vaccination zone is low.

3.4. Probability of spread within the buffer zone with vaccination

In the buffer zone with vaccination, cattle of all ages are vaccinated twice a year. Vaccinated animals are F-branded and do not leave the zone except when destined for slaughter. However, animals are not individually identified in every herd and this can lead to a low level of risk of cattle from the vaccination zone moving into the buffer zone without vaccination. Moreover in some areas, despite inspection and compulsory vaccination of cattle, vaccination coverage can be low for instance due to lack of motivation of veterinary technicians or local communities to visit the diptanks. Therefore, in some communal areas vaccination coverage of cattle herds can be below 60% if the diptank system collapses. The current risk of cattle herds being insufficiently immunised is considered to be low to moderate depending on the area, being higher in areas of communal farming and specially those where the involvement of communities in dip-tank surveillance is compromised. Moreover, the level of protection of the vaccine depends on the degree of similarity between the circulating strains of virus and attenuated strains used in the vaccine (Bastos, Haydon, Sangare, Boshoff, Edrich & Thomson 2003, Vosloo, Bastos, Sahle, Sangaré & Dwarka 2005). Until 2006, animals were vaccinated with trivalent (SAT-1, SAT-2 and SAT-3) vaccine consisting of buffalo isolates originating from KNP. However since 2006, the trivalent vaccine is purchased from other countries and the origin of the strains is likely to be distant from those circulating in KNP. Therefore, the level of protection of the current vaccine against FMDV challenges from the KNP buffalo population in cattle is probably lower, since efficiency of vaccines is directly linked with antigenic relations between the strains used for its production and the strains circulating in the field.

Conditions are more conducive for spread of infection in communal areas due to mixing of animals from different farmers at dip tanks and communal grazing areas. Moreover, individual farming units and animals are often not identifiable (Bruckner, Vosloo, Du Plessis, Kloeck, Connoway, Ekron, Weaver, Dickason, Schreuder, Marais

& Mogajane 2002). Therefore the probability of spread of the FMDV among cattle populations in the buffer zone with vaccination can be considered moderate.

3.5. The probability of transmission to the free zone

For an animal to be moved from the buffer zone with vaccination into the buffer zone without vaccination, it needs to be non vaccinated (non F branded) and quarantined for at least 21 days. During that period the animals are physically inspected and serologically tested. There is a possibility for some animals from the buffer zone with vaccination to occasionally cross illegally into the non vaccinated area. The probability of infected animals going undetected by physical inspection outside the buffer zone with vaccination is moderate, particularly if the clinical signs of the disease are mild. However, the probability of an infected animal going undetected by serology is negligible (the test has a sensitivity of 95% and specificity of 98%). Due to the implementation of these control measures, the probability of transmission from the buffer zone with vaccination into the buffer zone without vaccination is low.

For an animal to move from the buffer zone without vaccination into the free zone, it has to go through the same quarantine and control process. Therefore, the risk of an infected animal from the buffer zone reaching the free zone is considered negligible.

3.6. Exposure assessment

The probability of contact between escaped buffalo and cattle outside the park and the probability of transmission from excreting buffalo to cattle have both been rated as moderate and low, respectively. The probability of cattle in the buffer zone with vaccination developing the disease is rated as moderate in communal areas depending on the level of immunity among herds. Nevertheless, the probability of transmission and spread into the buffer zone without vaccination is rated as low. The probability of spread and transmission above the buffer zone without vaccination is rated as negligible. Therefore the exposure assessment can be qualified as moderate in the buffer zone with vaccination while it is considered low in the buffer zone without vaccination and negligible onwards.

4. Magnitude of consequences

The consequences of an outbreak of FMD outside KNP are solely economic, since the virus cannot be transmitted to humans and the public health consequences are null. Economic consequences can be direct, arising from the direct effects of outbreaks on production, but mainly on the costs of disease control (culling, vaccination) and restrictions on trade (movement control). Indirect impact comes from the costs of surveillance after the outbreak, fence management and maintenance, regular surveillance and monitoring activities at dip tanks and trade losses (impaired movement, embargoes, sanctions). The level of consequences will depend on the area where the outbreaks occur (Table 1). In the buffer zone, most consequences are biological and include calf mortalities, loss of milk production by lactating cows, loss of weight in beef cattle, secondary infection of hooves and teats. The impact of FMD control measures on the livelihoods of local communities such as strict movement control, insufficient trading opportunities or lack of availability of resources (grazing, water) is certainly more important than the impact of a single outbreak and should also be considered. However, since trading opportunities in the vaccination zone are limited, the impact of economic consequences at a national level, should an outbreak occur in the vaccination zone, can be considered as low. In the case of an outbreak spreading out of the buffer zone with vaccination, the economic impact becomes more important. The magnitude of consequences of an outbreak reaching the free zone are high (millions of Rands) since South Africa would loose its zoned FMD-free status for international trade in agricultural products, until the outbreak is contained and the FMD-free status re-established (at least during 3 months after the last clinical case).

5. General assessment

In the current situation, the overall situation of risk will differ depending on the season of the year and the FMD zone, where the consequences of an outbreak will be different. However, in all cases the result of the risk estimation regarding the occurrence of an outbreak and its consequences is moderate (see Table 1).

Table 1: Overall estimation of risk according to different scenarios.

Zone	Season	Combined probability of outbreak	Consequences	Risk estimation
Vaccination	Dry Rainy	Moderate Low	Low	Moderate Low
Non vaccination	Dry Rainy	Low	Moderate	Moderate
Free	Dry Rainy	Negligible	High	Moderate

DISCUSSION

The OIE risk analysis framework implemented in this study is usually a tool to manage disease risks associated with the imports of live animals or animal products from an exporting country (Murray 2004). The application of this method in the context of South Africa is innovative in that it measures the risk of hazard occurrence between different zones in the same territory.

Although most of the information provided in this study is not new, it provides a synthesis of the different outbreaks that had occurred during the last few years and a good basis for discussion between different role players as a part of the risk communication process. Our analysis shows that the probability of an FMD outbreak occurring outside of KNP is moderate due to a diversity of factors. In the first line of intervention, the pathway steps where the risks are higher and there is some margin of improvement are:

- o The increased permeability of the fence
- o The lower level of immunity among some herds in communal areas

Permeability of the fence is likely to be reduced by increasing surveillance and the pace of fence repairs along the fence perimeter. Management strategies for the control of elephant populations are under consideration in the KNP and the erection of a new fence system more solid but non electrified is being implemented in the north of the Park (D. Keet, personal communication).

In addition efforts in the buffer zone to maintain or improve the dip tank system and the implementation of vaccines containing the correct strains should allow an increase in the level of herd immunity and a subsequent mitigation of the risk of outbreak occurrence from moderate to low. Until those measures are improved, the risk of new outbreaks is at least moderate, particularly during extreme dry seasons and South Africa should take note of this. The experience acquired with previous outbreaks has shown that once the disease spreads among domestic cattle outside the KNP, active surveillance and emergency disease control actions have managed to identify and contain the disease before it reached the free zone, preserving the zoned disease-free status. On the other hand, these control measures clearly inhibit rural and social development of thousands of people living in the buffer zone and probably need re-assessment.

The qualitative risk assessment method presented here has clear limitations, especially regarding the choice and subjectivity of categories for the different parameters of risk chosen. However, it represents a first approach for a more comprehensive quantitative assessment which requires more time and available data. Equally, it provides a very useful tool to discuss different scenarios and disease management situations and to identify gaps of knowledge that can be used to manage other animal health challenges regarding at the wildlife/livestock interface in the context of TFCA's.

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